SOIL TEXTURE

IN RELATION TO

TOBACCO GROWING IN BRITISH COLUMBIA

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DOMINION OF CANADA
DEPARTMENT OF AGRICULTURE

BULLETIN No. 175—NEW SERIES

Published by direction of the Hon. Robert Weir, Minister of Agriculture,
Ottawa, 1935

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PREFACE

The purpose of this investigation has been to secure fundamental facts on the texture of soils of the tobacco producing areas of British Columbia in order that rational information may be available as to the suitability of these soils for the culture of various types of tobacco.

ACTUAL EXPERIENCE

is the only safe test of the suitability of climate and of soil for the production of tobacco possessing a certain type adapted to certain specific purposes as may be required by the trade.

DESCRIPTION OF SOILS OF TOBACCO PRODUCING AREAS OF OTHER PROVINCES AND COUNTRIES

Review of Literature

In 1927, Taylor (10) reported that in Southern Rhodesia the cultivation of flue-cured tobacco is practically limited to sandy loams of granite or sandstone origin, the mechanical composition of which is very similar to that of Norfolk fine sandy loam of North Carolina. These sandy loam soils vary in colour from almost white to pink and sometimes practically black when highly impregnated with organic matter. The surface soils are usually shallow, from four to nine inches in depth, and poor in plant food. Taylor further states that bright tobacco is also grown on sandy loams of red colour known as contact soils, which are found where granite and diorite, granite and schist, or granite banded ironstone are in contact. The contact sandy loams are finer in texture than those derived purely from granite and produce heavier yields of tobacco. This type of soil is seldom found in large continuous areas, but is probably the best soil for bright tobacco which is found in South Africa.

Dickson (5) in 1932 reported that the Australian tobacco soils contain about 46 per cent sand, 40 per cent silt, and 14 per cent clay. These soils contain much more silt and clay than typical flue-cured soils of North Carolina and in most cases the proportion of silt and clay is too high for the production of desirable flue-cured tobacco.

The United States Department of Agriculture reported that in the bright tobacco lands of Virginia and North and South Carolina, the soils recognized by practical farmers as being adapted to this crop are very light sandy soils containing not over 10 per cent of clay and composed largely of the medium grades of sand. Investigations have shown that the most favourable growing conditions are when the soil has between 6 and 8 per cent moisture. When the soils contain more than 10 per cent of moisture, they are too wet for the crop. When the soils contain less than 5 per cent of moisture, crops suffer.

Whitney (9) reported that tobacco soils of the best grade in the Connecticut Valley maintain, on an average, about 7 per cent of water throughout the season.

Nelson (8) in 1934 issued a leaflet in which he stated that, based on soil analyses and practical observations, a good soil for flue-cured tobacco and should contain about 75 per cent sand, 10 per cent silt and clay, 13 per cent coarse sand and gravel, and about 2 per cent organic matter. Some of the best flue soils in Norfolk county, Ontario, have only 5 to 6 per cent silt, clay and colloidal matter, with corresponding increases in the percentage of sand.

In 1930, Howell (6), a practical Burley grower of Tennessee, reported that a deep well drained soil, rich in humus, is best for the culture of Burley tobacco.

In 1929, Kinney (7) reported that good drainage of both surface and subsoil is especially necessary for the production of good Burley tobacco. The soil must be well supplied with plant food. Burley is distinctively a rich-land tobacco, and attempts to raise it on poor or even soils of moderate fertility, are certain to give disappointing results, unless manure or fertilizers, or both, are used liberally. Neither manure nor fertilizer will give good crops, however, on compact soils, low in organic matter, as physical condition of the soil is perhaps even more important than plant food content.

Whitney (9) states that the tobacco plant readily adapts itself to a great range of climatic conditions, will grow on nearly all kinds of soils, and has a comparatively short season of growth. But while tobacco can be so universally grown, the flavour and quality of the leaf are greatly influenced by the condi-

tions of soil and climate. The industry has become very highly specialized and the demand now is for tobacco possessing certain qualities, adapted to certain specific purposes.

Under given climatic conditions, the class and type of tobacco depend upon the character of the soil, especially on the physical character of the soil upon which it is grown, while the grade is dependent largely upon the cultivation and curing of the crop. The different types of tobacco are grown on a wide range of soils all the way from sandy land to heavy clay.

Nelson (8) states that soil type determines such important quality characteristics as colour, texture and body, as well as the nicotine content of the cured product.

The texture of tobacco soil can be determined by the method of mechanical analysis which consists of separating the particles of soil into grades of different sizes which are especially distinguished as gravel, sand, silt, and clay. The texture of a soil controls to a large extent its relation to water and the relative amount of water that it will contain. As a rule, the more clay a soil contains, the more water it will hold; for the spaces in the clay soil are so exceedingly small that the water moves very slowly and a relatively large proportion of the rainfall is retained for the use of plants.

Experimental Methods

The soil classification is based upon the U.S. Department of Agriculture, Bureau of Soils, Old Method. The pH values were determined by the colorimetric method and are probably correct within pH 0·2. The moisture equivalent is determined by the Briggs and McLane equipment. The other soil constants, such as wilting coefficient and total moisture holding capacity, were determined from the moisture equivalent data by the use of the empirical formulae suggested by Briggs and Shantz. From the data of actual moisture present at the time of sampling and the wilting coefficient, it is possible to estimate approximately the amount of available moisture present.

In the field care was exercised in selecting areas of land truly representative of the test. The selection was based upon the condition of the growing crop which was always sharply defined upon the various types of soil.

The type of soil container used was a round seamless tin can with close fitting tin lid. For moisture determinations, an eight-ounce size can was mostly used; for mechanical analyses, a sixteen-ounce size can or clean tightly-woven cotton sack. The cans were sealed with friction tape or with paraffin wax.

In taking samples of surface soil, 0 to 8 and 0 to 12 inches in depth, clean slices of soil were taken with a spade from freshly exposed side of six holes at widely divergent points of a representative area. The six slices of surface soil thus obtained were mixed on a canvas sheet after which the soil was rolled forward and backward in the canvas sheet until it was thoroughly mixed.

From the thoroughly mixed contents of the canvas, a sample was taken sufficient to closely pack an eight or sixteen-ounce size can, the amount depending on whether the sample was designated for soil moisture determination or mechanical analyses.

In taking samples of the lower soil horizons, one area only was selected of a representative type of soil and excavated to water table level. The exact location of the various soil horizons were clearly defined. From each soil horizon, six clean slices of soil were taken with a spade from the freshly exposed sides and mixed and packed similar to the method described for taking samples of surface soil.

In taking samples for moisture determinations, the utmost caution was exercised to not expose the soil to the drying effects of sun and wind. Representative type composite samples were collected as quickly as possible and immediately placed in clean tight seamless cans and sealed with friction tape or with paraffin wax and shipped to the laboratory.

Quantitative Measurements relating to the Movement and Retention of Water in Soils

Briggs, McLane and Shantz, 1907 and 1911 (1), (2), (3), reported that in the comparative study of soils, it is important to supplement the mechanical by quantitative measurements of other characters, especially those relating to the movement and retention of moisture.

These investigators determined four measurements relating to the movement and retention of water in soils, namely, the moisture equivalent, the wilting coefficient, the total moisture holding capacity, and moisture available. Their definitions of these uits of measurement of water in soils are given briefly in order to elucidate those sections of this report dealing with soil moisture determinations.

The moisture equivalent is the amount of water which a soil is capable of retaining when the soil moisture is subjected to a constant measured force sufficient in magnitude to remove the moisture from the larger capillary spaces. It represents the moisture which a soil must have in order to make it difficult to remove a very small additional amount of moisture. Thus, the moisture equivalent provides a means of determining and comparing the retentiveness of different soils for moisture when acted upon by a definite force.

The wilting coefficient of a soil is the moisture content of the soil at the time when the leaves of the plant growing in that soil first undergo a permanent reduction in their moisture content as the result of a deficiency in the soil moisture supply. By a permanent reduction is meant a condition from which the leaves cannot recover in an approximately saturated atmosphere without the addition of water to the soil. In the case of most plants, wilting accompanies this reduction of the water content of the leaves and is the criterion used to determine the wilting coefficient of a soil for that plant. Two independent variables enter into the determination of the wilting coefficient: (1) the moisture retentiveness of the soil used, and (2) the kind of plant used as an indicator.

The total moisture holding capacity is the percentage of water a soil can retain in opposition to the force of gravity when free drainage is provided.

The available moisture is the difference between the actual and the non-available water at any time. The non-available water in a soil is the soil moisture content when in equilibrium with the moisture of the air. Such a condition of equilibrium can at best be only approximate, since the saturation deficit of the air is constantly changing with the temperature. The water content which is available for growth is represented by the difference between the actual moisture content and the wilting coefficient.

SOILS OF THE BURLEY TOBACCO PRODUCING AREAS OF THE SOUTHERN INTERIOR IRRIGATED VALLEYS OF BRITISH COLUMBIA

Geography

The Burley[1] tobacco producing areas[2] of the irrigated valleys of the Southern Interior extend from the main line of the Canadian Pacific Railway, southward 250 miles to near the International Boundary. These areas include the districts of Ashcroft, Kamloops, Vernon, Lavington, Winfield, Kelowna, Summerland, Oliver, Grand Forks and Keremeos.

Description of the Land

The general aspect is that of a high rolling plateau, 1,130 to 1,500 feet in altitude, with numerous valleys which contain areas of arable bench and bottom land.

The bench lands are semi-arid and require irrigation to sustain cultivated crops. The benches vary from a few feet to several hundred feet in height, are usually broken by deep ravines, and are invariably without any active water table.

The bottom lands are mostly level, and may or may not require irrigation to support crop growth. The water table may vary from a few inches to sixty inches below the surface of the soil.

The soils, in general, are alluvial. Both surface and subsoils are mostly sandy loams. The subsoils are frequently underlain with sand, gravel, and sandy loam. The soils are extremely variable, typical of soils in a mountainous region.

All exposures are encountered: north, south, east and west; level, steep and rolling; sheltered and exposed; early and late.

Climate

The regional range in climate may be briefly summarized. The altitude above sea level varies from 1,000 to 1,700 feet, the average being about 1,300 feet. Clear, dry bracing atmosphere prevails with a noticeable absence of very severe storms. The day temperature is high but the mean temperature is moderated by persistently cool nights. The precipitation is light, the average being from 8 to 12 inches, and fairly well distributed throughout the year, but slightly higher in June and December. The amount of summer sunshine is very high, but low in November and December. The frost free period is generally sufficient for safe crop production.

Associated Natural Vegetation

Soil and climate determine the natural vegetation. The native plants growing on the land indicate the probable possibilities for crop production.

A few of the more common native plants characteristic of the tobacco producing areas of the Southern Interior are: western yellow pine (*Pinus ponderosa*), bunch grass (*Agropyron spicatum*), the sages (*Artemisia frigida* and *tridenta*), and balsam root (*Balsamorhiza sagittata*).

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[1] In these areas, commercial and experimental tests in the culture of various types of tobacco indicate that Burley is probably the safest type to grow. Cigar leaf may also be grown, but the successful production of this type of tobacco is attendant with greater risk than with Burley. In general, soil conditions in these areas are not suitable for the production of Green River and flue-cured types of tobacco.

[2] At the time of writing this report, the Burley producing areas are confined to the districts of Grand Forks and Kelowna only. Burley is the type of tobacco mostly grown.

Tobacco districts in Southern British Columbia.

These plants thrive on the naturally well drained sandy loam and very fine sandy loam soils. Their presence suggests semi-arid conditions typical of the bench lands of these areas.

Associated Cultivated Crops

Some of the more important cultivated crops grown in these tobacco producing areas are tomato, onion, cantaloupe, pepper, eggplant, asparagus, alfalfa, apple, and, in some of the more southern of these areas, sweet cherry, peach, and apricot. In general, these crops require much the same physical soil conditions as Burley tobacco, the well drained, deep, warm, sandy loams, and very fine sandy loams being mostly preferred.

Mechanical Analyses of Soils Producing Burley Tobacco

Mechanical analyses were determined of representative areas of soils of all Burley producing areas throughout the Southern Interior. The results of twenty-three analyses, representing thirteen districts, are given in Tables I and II.

TABLE I.—MECHANICAL ANALYSES OF SOILS WHICH PRODUCED THE BURLEY TOBACCO CROP IN THE IRRIGATED VALLEYS OF THE SOUTHERN INTERIOR OF BRITISH COLUMBIA—1925–1932

Soil No.	Soil acidity or hydrogen-ion concentration, 7·0 is neutral	Organic matter in soil (loss on ignition)	Mechanical analyses							Soil class
			Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	
	pH	%	%	%	%	%	%	%	%	
1	6·80	6·25	3·64	4·00	4·82	8·65	14·50	26·64	37·60	Clay
2	7·00	4·84	0·06	0·32	1·41	20·50	44·51	9·03	24·17	Sandy clay loam
3	6·70	4·72	0·96	2·15	4·26	14·93	32·23	28·74	16·73	Very fine sandy loam
4	7·50	5·21	0·45	0·81	2·36	14·10	39·54	27·86	14·88	Very fine sandy loam
5	7·60	4·76	0·08	0·26	2·29	18·30	51·79	13·34	13·94	Very fine sandy loam
6	7·17	10·30	0·41	1·14	3·35	12·72	25·30	43·30	13·78	Loam
7	7·00	7·88	8·56	7·35	5·20	13·49	28·82	25·26	11·32	Sandy loam
8	7·60	5·95	0·04	0·41	2·08	14·29	56·65	17·47	9·06	Very fine sandy loam
9	7·00	3·28	0·15	0·86	1·61	7·50	53·93	27·50	8·45	Very fine sandy loam
10	7·10	2·43	1·60	2·48	5·27	24·39	36·39	22·95	6·92	Very fine sandy loam
11	7·20	3·92	8·40	13·95	11·94	15·47	26·74	17·11	6·39	Sandy loam
12	6·60	....	6·29	11·91	10·76	17·40	27·72	19·25	5·97	Sandy loam
13	6·93	4·69	0·34	1·02	3·68	25·93	45·91	18·13	4·99	Very fine sandy loam
14	7·35	5·95	1·58	1·48	2·71	8·27	35·32	45·99	4·65	Loam
15	6·80	3·91	5·49	18·05	20·69	30·62	13·73	7·45	3·97	Sand
16	7·63	3·76	5·92	3·95	4·98	12·68	32·60	36·35	3·52	Very fine sandy loam
17	7·50	2·10	3·73	3·42	7·51	26·78	34·87	21·44	2·25	Very fine sandy loam
18	7·15	2·90	0·65	1·75	7·50	28·12	36·38	23·38	2·22	Very fine sandy loam
19	6·65	5·89	6·59	3·62	4·33	10·30	38·48	34·75	1·93	Very fine sandy loam
20	6·45	4·85	0·65	3·60	9·58	13·67	28·98	41·64	1·85	Sandy loam
21	7·20	1·90	11·55	4·55	5·68	13·52	31·09	31·86	1·75	Sandy loam
22	6·00	4·82	4·51	2·60	3·92	9·37	40·62	37·30	1·48	Very fine sandy loam
23	6·85	4·56	1·12	2·15	8·32	34·20	35·74	17·00	1·47	Loamy, very fine sand
Average..	7·03	4·77	3·16	3·99	5·84	17·18	35·30	25·81	8·66	

Depth of soil, 0 to 12 inches.
These analyses include soils from Kamloops, Vernon, Lavington, Winfield, Kelowna (including Glenmore, Belgo, Benvoulin and Okanagan Mission), Summerland, Oliver, Grand Forks, Keremeos.

TABLE II.—APPROXIMATE AVERAGE PERCENTAGE OF ORGANIC MATTER, GRAVEL, SAND, SILT AND CLAY, OF SOIL WHICH PRODUCED THE BURLEY TOBACCO CROP IN THE IRRIGATED VALLEYS OF THE SOUTHERN INTERIOR OF BRITISH COLUMBIA, 1925–1932.

Organic matter	Gravel	Sand	Silt	Clay
%	%	%	%	%
4·77	3·16	62·31	25·81	8·66

Depth of soil, 0 to 12 inches.

Comparison of Burley Crop Performance and Irrigation Requirement of Some of the Soils in Table I

Soil
No. District

1. *Kelowna*—heavy bottom land, irrigation usually not required, not suitable for Burley, more suitable for the culture of dark tobacco.
4. *Winfield*—level bottom land, no irrigation required, produces a heavy yield of good quality tobacco.
5. *Kelowna*—level bottom land, irrigation usually not required, depending on the character of the season. During the early part of the season this land is slightly too cool for promoting rapid growth. A heavy yield of leaf, thick in body and coarse in texture may be expected of this soil.
6. *Kelowna*—level bottom land, in some seasons may require a single moderate irrigation. This land produces a heavy yield of large coarse leaf.
7. *Grand Forks*—fairly level semi-bench land, several medium irrigations are required. This land produces a moderate yield of leaf of medium size and of desirable quality.
8. *Kelowna*—level bottom land, usually at least one irrigation is required, produces a fairly large yield of satisfactory quality.
9. *Kamloops*—fairly level semi-bench land, several medium irrigations are required, produces a fair yield of leaf of smooth texture and thin body.
11. *Summerland*—bench land with medium slope, several medium irrigations are required, produces a heavy yield of good quality.
16. *Kelowna*—level bottom land, irrigation usually not required, produces a heavy yield of fair to good quality leaf.
18. *Oliver*—fairly level semi-bench land, several medium irrigations are usually required. A moderate yield of fair quality leaf may be expected of this light soil.

An uneven patchy stand of Burley tobacco the result of unfavourable soil conditions due to alkali.

In comparing these soils, it should be noted that the character of the subsoil and underlying soil strata, the height of the water table, and exposure, may influence the irrigation requirements of a tobacco crop to a greater extent than the character of the surface soil.

Yield and leaf quality studies of Burley grown in these various districts indicate that a well drained, warm, deep, very fine sandy loam, rich in humus, is the most desirable for the culture of Burley.

Under irrigation the tendency of loam soil is to produce a heavy yield of large, coarse leaf.

Gravelly soil should be avoided in the culture of Burley tobacco.

In general, on the richer soils typical of the Southern Interior irrigated areas, and especially on the bottom land, the tendency of Burley when irrigated is to produce large coarse leaf.

Tables I and II show that in general the soils of the Burley areas are characterized with a pH value of about 7, being practically neutral, neither acid nor alkaline. The organic matter averages less than 5 per cent. The proportions of gravel, sand, silt and clay average approximately 3, 62, 26 and 9 per cent, respectively. The soils vary from very fine sand, to loam to clay, with a very fine sandy loam predominating. In general, these very fine sandy loam soils may be considered suitable for the production of Burley, provided the crop receives judicious husbandry .

Mechanical Analyses of Soils Producing Flue-cured Tobacco*

Mechanical analyses were determined of sixteen representative areas of soils producing flue-cured tobacco at Summerland.[1] The results of these analyses are given in Tables III and IV.

Table III.—Mechanical Analyses of Soils which produced the Flue-cured Tobacco Crop at Summerland, 1928–1932 (inclusive)

Soil No.	Soil acidity or hydrogen-ion concentration 7·0 is neutral	Organic matter in soil (loss on ignition)	Mechanical analyses							Soil class
			Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	
	pH	%	%	%	%	%	%	%	%	
1	*	....	9·51	18·57	13·41	15·66	20·13	10·65	12·05	Sandy loam
2	7·00	2·76	8·82	15·17	11·44	14·17	29·52	12·73	8·15	Sandy loam
3	....	3·68	3·69	6·58	8·12	24·11	33·32	16·17	8·01	Sandy loam
4	....	....	10·87	21·68	14·58	15·78	21·35	8·07	7·66	Loamy fine sand
5	....	3·91	2·79	7·25	10·66	28·20	29·41	14·75	6·94	Sandy loam
6	....	....	8·12	19·41	15·34	19·31	22·02	9·27	6·50	Loamy fine sand
7	7·20	3·92	8·40	13·95	11·94	15·47	26·74	17·11	6·39	Sandy loam
8	6·60	....	6·29	11·91	10·76	17·40	27·72	19·25	5·97	Sandy loam
9	7·00	2·20	14·70	18·70	17·03	15·67	18·30	9·67	5·93	Loamy sand
10	7·60	1·41	4·90	20·09	21·62	32·92	10·76	5·31	4·40	Sand
11	....	2·08	3·35	17·46	21·95	33·45	13·13	6·58	4·08	Sand
12	7·00	1·68	3·14	18·55	24·90	31·29	12·18	5·93	4·01	Sand
13	6·80	3·91	5·49	18·05	20·69	30·62	13·73	7·45	3·97	Sand
14	....	....	6·63	21·88	20·08	26·53	16·01	5·02	3·83	Sand
15	7·20	2·08	7·44	17·84	22·84	36·93	7·51	3·93	3·51	Sand
16	8·00	1·67	10·63	20·75	20·37	26·95	13·86	5·32	2·12	Sand
Average...	7·16	2·66	7·17	16·74	16·61	24·03	19·73	9·82	5·85	

Depth of soil, 0 to 12 inches. * No record available.

[1]In 1927 and 1928, commercial attempts to produce flue-cured tobacco were conducted in the districts of Oyama, Okanagan Mission, and Osoyoos, but resulted in failure, owing to inexperience of the operators.

*These soils are more suitable for the production of Burley tobacco.

Table IV.—Approximate Average Percentage of Organic Matter, Gravel, Sand, Silt, and Clay of Soil which Produced the Bright Flue-Cured Tobacco Crop, Summerland, 1928-1932.

Organic matter	Gravel	Sand	Silt	Clay
%	%	%	%	%
2·66	7·17	77·11	9·82	5·85

Depth of soil, 0 to 12 inches.

In comparison with the Burley producing land, Tables 3 and 4 show that the land selected for the production of flue-cured tobacco contains lower proportions of very fine sand, silt and clay, and higher proportions of fine gravel, coarse sand, medium sand, and fine sand. This land also contains less organic matter. The pH values indicate slightly higher alkalinity than the heavier land producing Burley. The soil class varies from sand, loamy sand, to sandy loam, with sand predominating, the proportion of sand being 77 per cent. In comparison with the texture of soils of older established bright flue tobacco areas, this land appears to contain similar texture or proportions of gravel, sand, silt and clay. However, actual field tests indicate that this land is not suitable for the production of bright flue tobacco. On the lighter areas of this land, during periods of high temperature, and low humidity, it is most difficult to sustain growth without wilting, even with the aid of irrigation. On the heavier land, the sandy loam, growth is too rank, maturity is too late, resulting in approximately 20 per cent immature leaf. Moreover, the leaf is too large and too coarse to cure a desirable quality.

Within these surface soil limits, sand, loamy sand, and sandy loam, gravelly areas are frequently encountered. Furthermore, although no detailed study of the texture of the soil profile was conducted, nevertheless, from the depth of cultivation downward, the subsoil and substrata may be considered as porous and containing extremely variable amounts of fine and coarse sand and gravel. This supposition of the general texture of the soil profile is well substantiated by the sandy, gravelly, porous soil as exposed by numerous deep road cuts and irrigation ditches in the vicinity. Accordingly, variableness of an open porous subsoil and substrata may be considered an important factor in the case of wilting or depressed growth in some plots while not in others, although containing only slight differences in the amount of clay and silt in the surface soil, for example, soil numbers 10, 11, and 14, in Table 3.

It would appear that a greater uniformity of desirable surface soil, subsoil, and substrata is required for flue-cured tobacco. Doubt may be cast on the possibility of finding in sufficient acreage such conditions of soil in the Interior Plateau, especially when the mode of formation of these soils is considered. Thus the production of flue-cured tobacco in the Southern Interior irrigated valleys may be expected to present a hazardous undertaking.

Comparison of Crop Performance on Some of the Soils in Table III

No. 1—For this type of tobacco, growth was outstandingly too heavy, late, green and immature at harvest. The yield was high, being 2,000 pounds per acre. The grade index was low, being 10·6.

No. 3—This crop response was similar to that of soil No. 1. At harvest, 50 per cent of leaf was immature.

No. 5—The growth was much too rank and heavy for the production of desirable leaf quality.

No. 6—This soil produced a good crop which yielded 1,500 pounds per acre. The grade index was 18·2.

No. 10—On this soil, tobacco wilted during high temperatures.
No. 11—A good crop, yielding 1,500 pounds per acre was produced on this soil.
No. 14—The crop on this soil was depressed in growth and yielded 600 pounds per acre. The grade index was low, being 8·8.
No. 15—In exposed areas, this soil is a blow sand. Even with adequate irrigation, it is difficult to sustain a tobacco crop on this soil during periods of strong wind and high temperature.
No. 16—Before the mechanical analysis of this soil could be determined, it was necessary to remove 45 per cent of stones. This soil was much too stoney and light for the production of tobacco.

Effect of Soil Variability on Yield, Grade Index, and Gross Value per Acre of Flue-cured Tobacco

Soil variability is typical of many areas of soil in these interior valleys, thus making difficult the securing of comparatively uniform conditions of soil, even to the extent of a few acres.

A study was conducted of selected small areas of crop receiving exactly similar culture, but growing on variable soil within a definite soil type.

The results are given in Table V.

Table V.—Effect of Soil Variability on Yield, Grade Index, and Gross Value per Acre of Flue-cured Tobacco, Summerland, 1931 and 1932

Variety	Plot	Yield per acre of cured leaf	Grade[1] Index	Gross value per acre
		lb.	cts.	$
1931				
Warne	1	1,016	4·5	41
	2	1,183	10·0	117
	3	2,023	11·8	239
	4	1,558	19·1	297
	5	1,471	13·3	196
Cash	1	428	13·4	57
	2	1,205	20·5	248
1932				
Hickory Pryor	1	1,619	15·1	244
	2	682	11·0	75
Gold Tip	1	1,103	15·0	165
	2	682	10·4	71
White Stem Orinoco	1	1,517	9·9	150
	2	668	6·2	41
Gold Leaf	1	1,466	11·7	171
	2	479	7·2	34

[1] The leaf is stripped into a number of groups according to the arrangement of the leaves on the plant; further assorted grades are made with respect to general quality. A price range is assigned to each grade according to quality, and the average value per pound is determined on this basis. This average computed price is called the "grade index". The "grade index", therefore, is based on the percentage of assorted grades and the relative commercial value of each grade. This method of evaluation was used to define the grade index value of tobacco presented in Table V.

The results in Table V show the necessity of selecting uniform land, suitable for the type of tobacco to be grown. The variable results in yield, grade and value of leaf indicate extreme variation of soil within this soil class which is designated by mechanical analyses as sandy loam. Such variable conditions of soil not only decrease the gross value of the crop per acre, but also increase the cost of production. Gross values per acre of 34, 41, 57, 75 and 150 dollars cannot be considered profitable production of tobacco.

Soil Moisture in Relation to the Culture of Tobacco in the Southern Interior of British Columbia

THE MOISTURE CONTENT AND MOISTURE AVAILABLE[1] DURING THE GROWING SEASON OF SOIL PRODUCING BURLEY AND FLUE-CURED TOBACCO, AT SUMMERLAND IN 1932.

The land used for this test is characterized as bench land and has no active water table and practically no dew. The land has a gentle southeasterly exposure. The soil varies from a gravelly loam to a sandy loam. Irrigation is necessary to sustain growth.

During the growing months of June, July and August, the precipitation was 0·21, 0·79, and 0·66 inch, respectively. The highest temperature of the season, 94° F., occurred on July 27 and on August 18. The lowest humidity of the season, 18 per cent, occurred on July 27 and 28. During July and August, the evaporation from an open tank was 0·153 inch per day.

During the season, five medium irrigations were applied, four of these being applied during July and August. No facilities were available for measuring the water.

Observation of the culture of commercial crops of tobacco in these areas indicate that irrigation is often applied in excess of crop requirement. In this experiment, an attempt was made to apply irrigation at approximately the minimum rate necessary to sustain normal growth. The results are presented in Table VI.

TABLE VI.—MOISTURE CONTENT AND MOISTURE AVAILABLE DURING THE GROWING SEASON OF SOIL PRODUCING BURLEY AND FLUE-CURED TOBACCO, SUMMERLAND, 1932

Crop	Approximate per cent moisture	
	In soil	Available
	%	%
Burley	8·39	2·97
Flue	7·25	2·41

Depth of soil, 0 to 12 inches.
Moisture determinations represent the average of 20 replications. Samples of soil for moisture determinations were taken at ten different times during the season.

In Table VI the soil moisture content of 8·39 and 7·25 per cent is considered too near the minimum, determined by careful observation of the growing crop. In fact, according to the wilting coefficient of these soils, 6·30 and 5·09 per cent (Table IX), the moisture content of these soils, 8·39 and 7·25 per cent, may be considered approaching near the moisture content of these soils at which permanent wilting takes place for this particular crop. This is somewhat substantiated by evidence of permanent wilting of plants here and there which were situated on the lighter soil areas. Accordingly, it is considered that a slightly higher moisture content and moisture available would have approached nearer the soil moisture requirement of these soils for this crop.

Notwithstanding the soil moisture being maintained near the wilting coefficient of these soils for this crop, a good yield of both bright flue and Burley tobacco was harvested which graded about medium in quality.

In general, the soil moisture requirement of tobacco as indicated by this experiment, tallies closely with previous investigations conducted of tobacco soils of Virginia, North and South Carolina and the Connecticut Valley, presented on pages 6 and 7.

[1] Explanation of the terms "Moisture Equivalent", "Wilting Co-efficient", "Total Moisture Holding Capacity" and "Moisture Available" is given on page 7.

In the culture of this exacting crop, approximate satisfactory soil moisture relations are most difficult to obtain on the variable soils typical of these Southern Interior valleys. In these areas, the irrigation of tobacco may be expected to present major cultural problems. These problems can be determined only by actual cultural experience of the particular environment under which the crop may be grown. Invariably, the environment is different on each farm.

The results of this experiment indicate that where irrigation is practised in the culture of tobacco, water should be sparingly applied.

THE MOISTURE EQUIVALENT, WILTING COEFFICIENT, AND TOTAL MOISTURE HOLDING CAPACITY OF SOIL PRODUCING BURLEY AND FLUE-CURED TOBACCO

The moisture equivalent indicates approximately the type of soil and the amount of organic matter present. Soils with a low moisture equivalent contain considerable amounts of sand and very little clay. The finer the soil texture, the greater is the moisture equivalent. For example, a purely clay soil might have a moisture equivalent of 45 per cent. As a rule, the more clay a soil contains, the more water it will hold. This is well illustrated in Tables IX and X.

For comparison, the moisture equivalent and wilting coefficient for soils of different textures by Briggs and McLane (1) are given in Tables VII and VIII.

Table VII.—The Moisture Equivalent for Soils of Different Textures

Soil Texture	Moisture equivalent
	%
Coarse sand	4·6
Fine sandy loam	6·8
Loam	18·9
Silt loam	24·4
Clay loam	32·4
Clay	38·2

Table VIII.—The Wilting Coefficient for Soils of Different Textures

Soil texture	Wilting coefficient
	%
Coarse sand	0·9
Fine sand	2·9
Sandy loam	5·5
Fine sandy loam	9·7
Loam	12·1
Clay loam	16·3

Table IX.—Moisture Equivalent, Wilting Coefficient and Moisture Holding Capacity of Soil Producing Burley and Flue-cured Tobacco, Summerland, 1932
(Soil class—sandy loam)

Crop	Moisture equivalent	Wilting coefficient	Total moisture holding capacity
	%	%	%
Burley	11·58	6·30	39·11
Flue	9·36	5·09	35·71

Depth of soil, 0 to 12 inches. Average of 20 replications.

Table IX shows that the moisture equivalent and wilting coefficient in relation to soil texture are somewhat similar to the findings of Briggs and McLane in Tables VII and VIII applied to a sandy loam.

A much closer similarity of moisture equivalent was obtained with the Vernon series of United States soils which record a moisture equivalent of 10·3 for sandy loam, the Summerland moisture equivalent averaging 10·47 per cent for sandy loam.

It is generally considered that Burley requires a finer or heavier soil than bright flue tobacco. Thus, in selecting land for these two types of tobacco, soil requirements were especially considered. In Table IX, it will be noted that the soil which produced the burley has a higher moisture equivalent, thus designating a soil finer in texture and containing more clay than the soil which produced the bright flue crop.

Under the particular environment of these irrigated bench lands, a soil having a moisture equivalent of about 12 per cent produces burley of good yield and of medium to good quality. For flue-cured tobacco, however, a moisture equivalent of about 9 per cent appears to be too high, the leaf tendency being too large and too coarse to secure the desired quality.

The wilting coefficient is the moisture content of the soil at which permanent wilting occurs. Barnes (1) reports that it is a fair indication of the line of separation between moist and dry soils.

Barnes (1) further reports that in the Swift Current area of Saskatchewan he has frequently noticed that the moisture content of field samples of soil, while well above the wilting coefficient, may be below the moisture equivalent. Tables VI and IX record similar results at Summerland, the soil moisture content being below the moisture equivalent.

In general, soils having a lower wilting coefficient than 5 per cent are considered not suitable for profitable tobacco production in these areas.

The total moisture holding capacity of these gravelly loam and sandy loam bench soils is seldom realized by natural precipitation or by irrigation, if judiciously applied.

The culture of tobacco under soil conditions of too high a total moisture holding capacity may be expected to very materially depress normal growth and often tends to develop major disturbances within the plant, especially that of Frenching, a physiological disease.

THE MOISTURE EQUIVALENT, WILTING COEFFICIENT, AND TOTAL MOISTURE HOLDING CAPACITY OF LAND PRODUCING BURLEY TOBACCO, BY DISTRICTS

These soil moisture tests are compared for three Burley tobacco producing districts, namely, Summerland, Kelowna, and Grand Forks. The results are given in Table X.

Table X shows that as the land graduates from bench to semi-bench to bottom land, there is a progressive increase in the proportion of clay. Moreover, as the proportion of clay increases, so does the moisture equivalent, wilting coefficient, and moisture holding capacity of the soil. Thus, the finer the soil texture, the higher the clay content, the higher the moisture equivalent and the greater the capacity of the soil to hold moisture and sustain plants from wilting.

The bottom land is classed as a very fine sandy loam. This land is level and contains an active water table, 60 inches below the surface. Irrigation may or may not be necessary to sustain a tobacco crop, depending on the character of the season. This land produces a heavy yield of large coarse leaf tobacco.

The semi-bench land is a sandy loam and has a gentle northwesterly exposure. Several medium irrigations are necessary to sustain a tobacco crop. This land produces Burley which compares favourably in quality with Burley produced on bench land. A high percentage of bright leaf, high in grade value and yielding about 1,600 pounds per acre may be expected of this class of land.

The bench land is a sandy loam and has a southeasterly exposure. This land has no active water table. Several medium irrigations are necessary to sustain a crop of tobacco. This land is capable of producing heavy yields of medium to good quality Burley tobacco.

TABLE X.—THE MECHANICAL ANALYSES OF LAND PRODUCING BURLEY TOBACCO IN RELATION TO THE MOISTURE EQUIVALENT, WILTING COEFFICIENT AND TOTAL MOISTURE HOLDING CAPACITY, BY DISTRICTS AND BY CLASS OF LAND

District	Class of land	Organic matter	Mechanical analyses of land producing burley							Moisture equivalent	Approximate	
			Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay		Wilting coefficient	Total moisture holding capacity
		%	%	%	%	%	%	%	%	%	%	%
Kelowna	Bottom	4·76	0·08	0·26	2·29	18·30	51·79	13·34	13·94	19·58	10·64	51·74
Grand Forks	Semi-bench	7·88	8·56	7·35	5·20	13·49	28·82	25·26	11·32	15·20	8·26	42·86
Summerland	Bench	3·92	8·40	13·95	11·94	15·47	26·74	17·11	6·39	11·86	6·34	39·11

Depth of soil, 0 to 12 inches.

THE SOILS OF THE TOBACCO PRODUCING AREA AT SUMAS LOWER MAINLAND, BRITISH COLUMBIA

Geology[1]

Geologically, the Sumas Lake deposit is probably of recent age. The soil is derived from alluvium and glacial drift deposits. Sandstone, limestone, shale, granite, and conglomerate, comprise some of the more commonly known rocks of the nearby mountains.

History of the Lake Area[2]

The Fraser river backed into this area at freshet time, but the main feeder to the area at all times was the Vedder river. This was supplemented to a considerable extent by the Saar-Arnold and Sumas creeks.

The lake was drained during the early spring of 1924. The water level of the area is protected by a dyking and pumping service. Since reclamation, the area has been utilized for general mixed farming, with field peas, red clover, hops, tobacco and sugar beets as special crops.

Geography

The Sumas Valley is situated on the Lower Mainland of British Columbia, about sixty miles southeast of Vancouver. The flue-cured tobacco producing area in this valley is situated about six miles north of the 49th Parallel and about midway between the towns of Abbotsford and Chilliwack.

Topography[2]

The valley of the Sumas lies generally in a northeasterly and southwesterly direction. It is three and two-thirds miles in its narrowest section and about twelve miles wide in its widest section. For the most part the valley is bordered on either side by mountains having an altitude of approximately 2,000 feet. The bottom of the reclaimed lake area is 2·87 feet below mean sea level. The altitude graduates from 2·87 to 32·1 feet above mean sea level. The rim of the lake area is approximately 10 feet above mean sea level. Practically the entire area is level open land.

Climate

Owing to the proximity of the Pacific Ocean, the climate is moderate. During the growing season, the nights are usually cool and the breezes are mostly southwesterly. The season is late in warming up in the spring. There is little danger of frost or hail injury to timely, well-grown crops of tobacco. During May and June, fairly steady moderate cool breezes prevail in the more exposed areas. During September and October, rain and wind are the major climatical conditions to be reckoned with in the ripening, harvesting and curing of late crops of flue-cured tobacco.

The nearest meteorological station where temperature records are available is at Chilliwack which is situated from six to eight miles from the lake area. The latter is considered cooler in spring and slightly warmer in summer than the Chilliwack area. Moreover, the lake area has better air drainage and is freer from frost for a somewhat longer period than is the Chilliwack area. The average temperature at Chilliwack is presented in Table XI.

[1] Dominion of Canada Geological Survey.
[2] Report of Bruce Dixon, Sumas Commissioner.

Table XI.—Temperature at Chilliwack—Average 33 Years, 1899 to 1932

Degrees Fahrenheit

March	April	May	June	July	Aug.	Sept.	Oct.
41	49	52	60	64	63	58	50

A record of precipitation was secured from the pumping station which is located close to Sumas Mountain at the northeast side of the valley. Further out towards the centre of the valley, away from the sheltering influence of the mountain, slightly higher precipitation may be expected. However, Table XII records a fairly reliable index of the amount of precipitation throughout the tobacco producing area of the Sumas.

Table XII.—Precipitation at Sumas—Average 10 Years, 1924 to 1933

Inches

March	April	May	June	July	Aug.	Sept.	Oct.
6·15	4·01	3·52	2·88	1·08	1·24	4·54	6·39

The extremes of low and high precipitation during the growing seasons throughout this period are presented in Table XIII.

Table XIII.—Extremes of Precipitation

Month	Extreme of precipitation during 10-year period	
	Low	High
	in.	in.
March	1·53	11·01
April	2·84	5·71
May	1·12	6·97
June	0·48	6·48
July	0·09	3·33
August	0·00	3·86
September	0·98	10·03
October	3·15	12·10

Drainage[1]

The lake area at Sumas being practically level is subject to surface floods during periods of exceptionally heavy rains. These rains occur generally in the late fall, winter and early spring. Owing to the open sandy character of the soil, the water drains away quickly when implemented by surface drains to the large ditches which all drain to a central large lake canal. Through continuous pumping service the aim is to maintain the water in the canal at a low enough level to facilitate rapid drainage.

Weeds

The much branched green wiry perennial, common horsetail (*Equisetum arvense*) thrives abundantly throughout the entire area. This weed may be considered a major pest of the tobacco crop at Sumas. Another weed which flourishes in certain sections is a low woolly annual, low cudweed (*Gnapha-*

[1] Report of Bruce Dixon, Sumas Commission.

lium uliginosnosum) and Canada thistle (*Cirsium arvense*). The common willow rapidly covers uncultivated areas and persistently encroaches on cultivated land. Thus, the willow is classified as a troublesome weed in this area.

Field and Garden Crops

Red clover (*Trifolium pratense*) thrives throughout the entire Sumas area, and is the major forage crop. Oats, sugar beets, and field peas thrive on the heavier of the Sumas soils. Hops grow well and are an important crop. Corn and tomatoes attain only fair maturity. Beets, carrots, potatoes, peas, beans, and onions produce good yields.

Mechanical Analyses of Soils Which Produced a Normal Crop of Flue-cured Tobacco

In Table XIV are presented the mechanical analyses of eight areas of medium sandy soil typical of some tobacco producing areas at Sumas. Under present known methods of culture, this type of soil produces a normal crop of from 700 to 800 pounds of cured leaf per acre.

Of these eight areas of soil, those numbered 10 and 11, produced the best yield and quality. Number 10 developed no wasting of bottom leaf, produced eight leaves per plant, and yielded 800 pounds per acre. Number 11 developed slight wastage of bottom leaf, produced from seven to eight leaves per plant, and yielded 700 pounds per acre. Thus, it would seem that the higher proportion of very fine sand, silt and clay induced higher yield and quality, the result of greater moisture sustaining power during the dry hot days of midsummer.

Table XIV.—Mechanical Analyses of Soils which produced a Normal Crop of Flue-cured Tobacco—Sumas, 1932

Soil No.	Mechanical analyses						
	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	%	%	%	%	%	%	%
8	2·32	3·44	7·06	52·32	30·98	2·03	1·85
9	0·18	0·67	1·52	43·03	49·22	3·30	2·08
10	0·05	0·30	0·72	23·66	59·91	9·26	6·10
11	0·15	0·69	1·91	25·10	60·31	7·77	4·07
12	5·87	12·06	24·45	40·06	12·89	2·33	2·34
13	0·15	0·57	1·21	39·66	49·80	4·66	3·95
14	5·56	18·15	23·95	37·19	11·45	2·39	1·30
15	0·20	0·69	2·23	44·90	40·00	8·04	3·94
Average	1·81	4·57	7·88	38·24	39·32	4·97	3·20

Depth of soil, 0 to 12 inches.

Mechanical Analyses of Soils Which Produced a Poor Crop of Flue-cured Tobacco

In Table XV are presented the mechanical analyses of seven areas of light sandy soil typical of some tobacco producing areas at Sumas. The crop response indicates that this soil contains too low a proportion of silt and clay to sustain normal crop development.

This light soil is subject to slight blowing, sufficient, however, to harass and depress a stand of tobacco and, especially so, in the more wind-swept areas and when small weak plants are used.

Moreover, on this type of soil, the stand of tobacco is short, uneven, and patchy. Growth is depressed, developing only from three to four leaves per plant. During the mid-season period of growth, the crop suffers from sun-burn-

ing, firing and wasting of leaf, the result of inadequate soil moisture. The yield is from 100 to 300 pounds of poor quality leaf per acre.

As these lighter sandy areas become known as being unsuitable for the culture of tobacco, they should be utilized in the production of other crops which involve less financial risk and which tend to improve the condition of the soil.

With judicious soil management, some of these lighter soil areas may yet prove suitable for the successful production of flue-cured tobacco. However, unless market demands warrant a large increase in acreage, the production of flue-cured tobacco should be limited to the medium sandy soil which is now known to be the most suitable of the various soil types of this tobacco producing area.

TABLE XV.—MECHANICAL ANALYSES OF SOILS WHICH PRODUCED A POOR CROP OF FLUE-CURED TOBACCO—SUMAS, 1932

Soil No.	Mechanical Analyses						
	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	%	%	%	%	%	%	%
1	0·81	4·83	18·87	60·12	12·89	1·36	1·12
2	0·27	0·74	1·84	51·37	38·92	4·29	2·57
3	6·47	15·32	26·23	39·27	9·21	1·94	1·56
4	1·60	2·85	5·40	63·75	21·64	3·53	1·23
5	2·54	3·57	4·10	25·76	55·09	6·18	2·76
6	0·06	0·47	4·03	64·36	27·15	2·09	1·84
7	2·25	6·97	11·56	43·90	28·44	4·39	2·49
Average	2·00	4·96	10·29	49·79	27·62	3·40	1·94

Depth of soil, 0 to 12 inches.

Mechanical Analyses of Soils which Produced Flue-cured Tobacco, Coarse in Texture, Thick of Body, and Late in Maturing

In Table XVI are presented the mechanical analyses of two areas of heavy sandy type of soil typical of the marginal land of the lake area. The crop response indicates that this soil contains too large a proportion of silt and clay which produces a large coarse leaf which matures late, resulting in much wastage of leaf through the effects of wind, rain and temperature. Moreover, this type of soil produces tobacco darker in colour than is generally required by the trade. Although the yield is usually high, the quality is usually too low to secure profitable returns. This type of soil appears to be more adapted to growing the general farm crops of this district, such as sugar beets, field peas, red clover and grain.

Soils number 1 and 2 of these areas yielded at the rate of 1,200 to 600 pounds of cured leaf per acre, respectively. Soil number 2 developed only 40 per cent maturity.

TABLE XVI.—MECHANICAL ANALYSES OF SOILS WHICH PRODUCED FLUE-CURED TOBACCO, COARSE TEXTURE, THICK OF BODY, AND LATE IN MATURING, SUMAS, 1932

Soil area No.	Organic matter	Gravel (fine)	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay.
	%	%	%	%	%	%	%	%
1	3·70	2·14	7·24	12·85	37·55	18·93	10·17	11·12
2	2·98	1·09	2·67	4·35	22·72	34·29	29·94	4·94

Depth of soil, 0 to 12 inches.

Soil Profiles

In the Sumas tobacco producing area, the character of the soil from the surface to the water table level has an important influence on the yield and quality of tobacco produced. To determine the extent of this influence, tests were conducted of the character of the soil to water table level of representative areas producing normal and poor crops of tobacco.

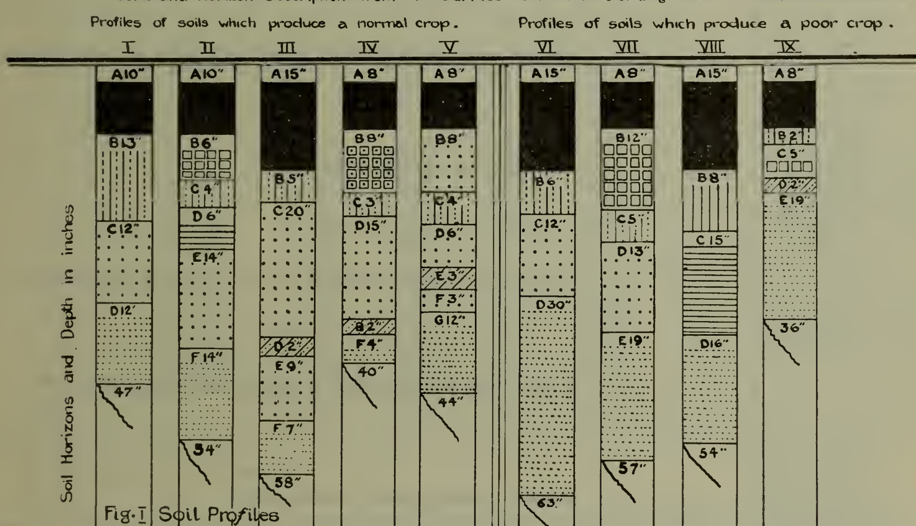
The tests comprised a study of nine soil profiles to water table level. These profiles were located at widely divergent points throughout the tobacco producing areas, five being in areas which produce a normal crop and four in areas which produce a poor crop.

The character of these profiles in relation to yield and quality of tobacco was determined (1) by a description of the soil, (2) by mechanical analyses, (3) by the amount of organic matter present, (4) by the degree of soil acidity, and (5) by careful observation of the response of the crop to the profile area.

The tabulated results of these tests are presented in Tables XVII, XVIII, XIX, XX and XXI.

SOIL PROFILES

Profile and Horizon Description from the Surface to Water Table of Bright Flue Cured Tobacco Soils at Sumas



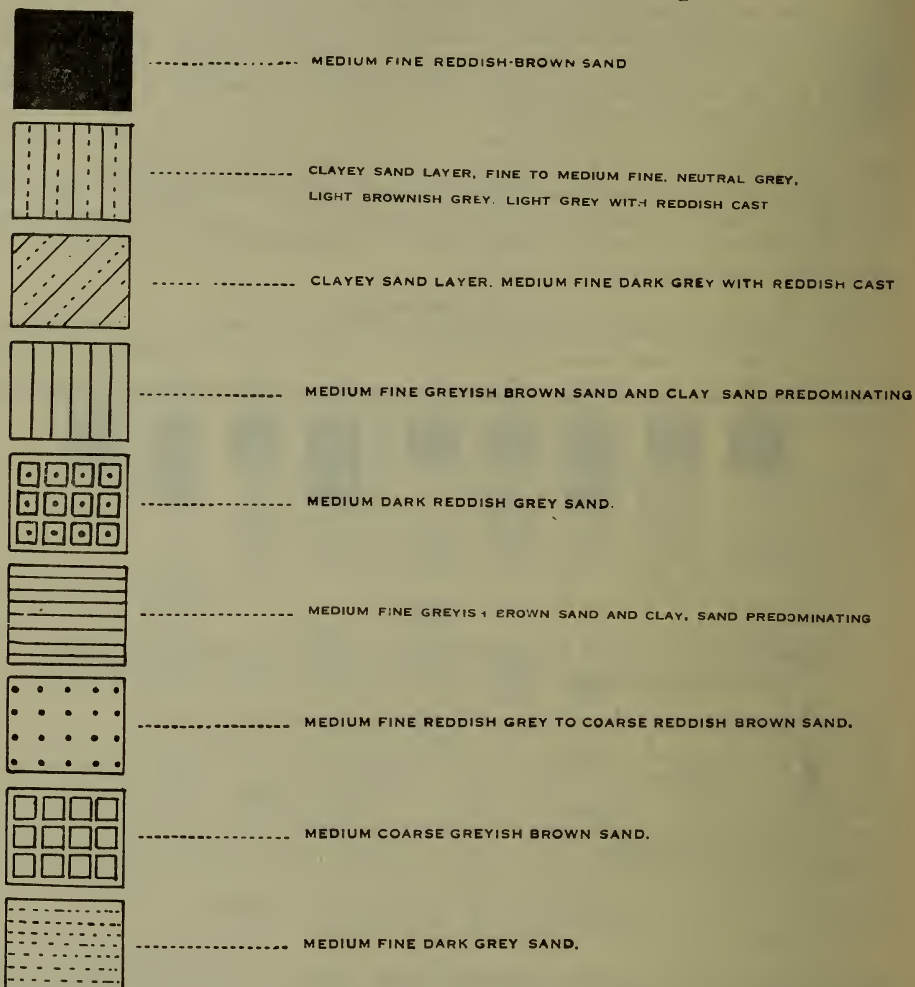
DESCRIPTION OF THE SOIL—BY PROFILE

The soil of the normal crop producing areas may be described as medium fine, reddish-brown sand, 8 to 15 inches in depth, underlain with a medium fine light grey clayey sand layer with a reddish cast to a depth of from 3 to 5 inches, or a medium coarse dark reddish-grey sand to a depth of 5 to 8 inches, where it changes to a medium fine reddish-brown sand to a depth of 12 to 20 inches. At this depth, varying from 20 to 40 inches, there is a second clayey sand layer, dark grey with a reddish cast, 2 to 3 inches in depth, underlain with coarse reddish brown sand to a depth of from 3 to 9 inches, below which is a medium fine dark grey sand varying from 7 to 13 inches in thickness to the water table which varies from 40 to 58 inches.

The soil of the poor crop producing areas has much the same general character and formation as in the normal crop producing areas, but with these exceptions: the poor crop areas have a lower proportion of silt and clay; moreover, the medium fine dark grey sand horizon which always contains the water table is invariably nearer the surface.

In general, with both normal and poor producing areas, from the surface to the water table, there are four to seven distinct soil horizons. The depth of the water table varies from 36 to 63 inches, the average depth being about 50 inches. The water table is always situated in a thick layer of medium fine dark grey sand.

A graph and key of the profiles studied are given in Figs. 1 and 2.



COLOUR INTERPRETATION.

IN DESCRIBING THE COLOUR OF THESE SOILS, THE MUNSELL COLOUR CHARTS WERE USED IN A NORTH LIGHT. THE SOILS WERE ARRANGED ACCORDING TO COLOUR TENDENCIES FROM RED, BROWN, TO REDDISH GREY TO NEUTRAL GREY TO DARK GREY.

FIG. 2 KEY TO SOIL PROFILES.

Some characteristics of the crop performance of five of these profiles are discussed:—

Profile II—By September 1, the crop ripened 8 to 10 leaves per plant, the leaves being 24 to 26 inches in length and 8 to 10 inches in width.

Profile III—Yielded at the rate of 800 pounds per acre.

Profile VII—Developed plants from 3 to 10 inches in height and 3 to 6 leaves per plant, the leaves being 10 to 20 inches in length. The plants yellowed but did not fully ripen.

Profile VIII—Yielded at the rate of 300 pounds per acre.

Profile IX—A blow sand. On this light shifting soil, it is most difficult to establish a stand of plants. In summer, this soil is too dry to sustain normal growth. Its capacity to yield is only about 200 to 300 pounds per acre.

MECHANICAL ANALYSES OF SOIL PROFILES 1932

Mechanical analyses were determined of each soil horizon from the surface to the water table of two areas which produce a normal crop, and of two areas which produce a poor crop.

The results of these analyses are given in Tables XVII and XVIII.

TABLE XVII.—MECHANICAL ANALYSES OF SOIL HORIZONS FROM SURFACE TO WATER TABLE OF LAND WHICH PRODUCED A NORMAL CROP OF FLUE-CURED TOBACCO, SUMAS, 1932

Profile No.	Horizon depth	Mechanical analyses						
		Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	in.	%	%	%	%	%	%	%
4	0–8	5·56	18·15	23·95	37·19	11·45	2·39	1·30
	9–16	8·41	35·90	33·42	21·09	0·52	0·46	0·00
	17–19	2·84	9·08	14·72	26·75	23·07	8·55	14·99
	20–34	3·54	14·91	27·50	47·00	4·86	0·51	1·68
	35–36	9·81	24·32	19·55	13·30	18·14	6·02	8·86
	37–40	15·28	36·95	20·51	24·60	1·82	0·73	0·11
2	0–10	0·20	0·69	2·23	44·90	40·00	8·04	3·94
	11–16	3·10	11·89	22·27	56·28	5·32	0·76	0·38
	17–20	2·36	3·75	14·27	27·25	35·97	5·74	10·66
	21–25	4·23	11·95	21·21	45·82	12·35	2·49	1·95
	26–39	1·96	8·60	19·11	65·05	3·87	0·75	0·66
	40–54	4·77	18·05	31·60	40·00	3·36	1·11	1·11
Average		5·17	16·19	20·86	37·44	13·39	3·13	3·80

Soil classification: fine sand.

TABLE XVIII.—MECHANICAL ANALYSES OF SOIL HORIZONS FROM SURFACE TO WATER TABLE OF LAND WHICH PRODUCED A POOR CROP OF FLUE-CURED TOBACCO—SUMAS, 1932

Profile No.	Horizon depth	Mechanical analyses						
		Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	in.	%	%	%	%	%	%	%
8	0–8	2·25	6·97	11·56	43·90	28·44	4·39	2·49
	9–20	2·94	10·98	27·62	52·55	4·71	0·69	0·51
	21–25	0·45	0·99	1·14	6·36	73·28	11·35	6·43
	26–38	0·67	4·94	14·67	59·38	17·57	1·68	1·09
	39–57	6·05	15·56	27·43	46·96	2·24	0·41	1·35
9	0–8	0·06	0·47	4·03	64·36	27·15	2·09	1·84
	9–10	0·04	0·32	0·67	51·89	41·93	2·73	2·42
	11–15	0·10	0·66	3·65	73·63	19·42	1·15	1·39
	16–17	0·92	3·05	6·18	30·95	51·37	4·37	3·16
	18–36	1·11	8·61	21·38	64·68	3·43	0·51	0·28
Average		1·46	5·25	11·83	49·47	26·95	2·94	2·10

Soil classification: fine sand.

The analyses in Tables XVII and XVIII show some interesting comparisons of soil profiles between normal and poor crop producing areas.

The total percentages of clay and silt of all soil horizons from the surface to the water table of the normal crop producing areas are 22·82 and 18·77, being 12·39 and 4·09 per cent higher, respectively, than the clay and silt content of the various soil horizons of poor producing areas.

The average percentage of clay and silt of the soil horizons from the surface to the water table of the normal producing areas are 3·80 and 3·13, being 1·70 and 0·19 per cent higher, respectively, than the clay and silt content of the various soil horizons of poor producing areas.

Furthermore, the normal crop producing areas contain a fairly consistent higher percentage of fine gravel, coarse sand, and medium sand, and a lower percentage of very fine sand and fine sand. The results of these analyses indicate that the proportion of clay and silt to sand is to a large extent the major soil factor influencing crop production.

MECHANICAL ANALYSES OF SOIL PROFILES—AVERAGE OF THREE YEARS, 1930-1932

Mechanical analyses, extending over a period of three seasons, 1930 to 1932, were conducted of soil profiles extending from the surface soil to the water table of representative areas producing normal and poor crops of tobacco.

The results of these analyses are given in Table XIX.

TABLE XIX.—PERCENTAGE OF ORGANIC MATTER, GRAVEL, SAND, SILT AND CLAY OF SOILS WHICH PRODUCED THE FLUE-CURED TOBACCO CROP, SUMAS, 1930–32

Soil description	Organic matter	Gravel	Sand	Silt	Clay
	%	%	%	%	%
Normal crop area—					
Surface soil (0 to 12 inches)	3·16	1·81	89·64	4·97	3·20
Average of soil horizons, surface to water table (0 to 49 inches)	2·65	5·17	87·88	3·13	3·80
Poor crop area—					
Surface soil (0 to 12 inches)	2·29	2·00	92·67	3·40	1·93
Average of soil horizons, surface to water table (0 to 54 inches)	2·13	1·46	93·50	2·94	2·10

Table XIX shows that in the normal crop producing areas, the surface soil and the average of the soil horizons to the depth of the water table, contain a higher percentage of organic matter, silt and clay, than the poor crop producing areas. The higher proportions of organic matter, silt and clay, while not large, yet are sufficient to materially influence crop production, thus emphasizing how very exacting are the soil requirements for the successful cultuie of flue-cured tobacco.

ORGANIC MATTER

Soils suitable for the production of flue-cured tobacco are low in organic matter, the amount usually being between 2 and 3 per cent.

The amount of organic matter at various depths from the surface soil to the water table of areas producing normal and poor crops of tobacco is presented in Table XX.

The results given in Table XX show that normal crop producing areas contain 0·53 per cent more organic matter than poor crop producing areas. The difference, while not large, is sufficient to materially influence the production of this type of tobacco. In general, the amount of organic matter present in the soil of the lake area at Sumas is similar to that of other bright flue tobacco producing areas.

Table XX.—Organic Matter of Flue-cured Tobacco Soil, Sumas, 1931 and 1932

Number of replications	Depth of soil	Soil area	Percentage organic matter
	in.		%
8	0– 8	Producing a normal crop	2·99
8	0– 8	Producing a poor crop	2·46
8	48	At water table	1·83
28	0–48	Surface to water table	2·91
		Average	2·55

SOIL ACIDITY

The degree of soil acidity is influenced by the original constitution of the soil, by the organic matter present, and by the kind of fertilizer applied.

There being very little humus in the soil of the lake area at Sumas, and, to date, very little fertilizer applied, the present degree of soil acidity is probably mostly derived from the original constitution of the soil. This is somewhat substantiated in Table XXI which shows scarcely any difference in the degree of soil acidity between the upper and lower soil horizons.

Owing to the sensitiveness of the tobacco plant to environment, it is important that the acidity of the soil be considered. Thus, in the culture of bright flue tobacco, where annual heavy applications of commercial fertilizers are applied, it is especially important to use the kind of fertilizer which tends to produce suitable soil acidity. Moreover, the degree of acidity should be determined each year before deciding on the exact fertilizer to apply to the season's crop.

In general, a soil of medium acidity, approximately pH 6, is considered suitable for tobacco.

Table XXI.—Soil Acidity or Hydrogenion Concentration of Flue-cured Tobacco Soil, Sumas, 1931 and 1932

(pH 7·0 is approximately neutral, neither acid nor alkaline; pH 6·0, pH 5·0 or pH 4·0 indicate increasing degrees of acidity; while pH 8·0, pH 9·0 or pH 10·0 represent increasing degrees of alkalinity.)

Soil description and depth	pH
Surface soil, 0 to 8 inches	6·3
Soil horizon at water table, 50 inches	6·0
Average of soil horizons, surface to water table	5·9*
Average	6·1

* pH 5·9 is the average of 28 determinations. Lowest pH, 5·0 Highest pH, 6·8.

Yield of Flue-cured Tobacco in Relation to Mechanical Analyses and Soil Moisture Relations

Soil and water relations were determined of two areas of land producing poor crops of flue-cured tobacco. These determinations were conducted at harvest time. The estimated yields, mechanical analyses and soil moisture relations of these areas are presented in Table XXII.

For the production of flue-cured leaf of desirable quality, these areas contain too high a proportion of clay and silt and too high soil moisture relations. Such conditions of soil and moisture tend to produce large, coarse dark leaf which usually grades a high proportion of low quality tobacco. Furthermore, growth is sustained too late in the season, which tends to produce im-

TABLE XXII.—YIELD OF FLUE-CURED TOBACCO IN RELATION TO MECHANICAL ANALYSES AND SOIL MOISTURE RELATIONS, 1931

Soil area No.	Estimated yield per acre	Organic matter	Mechanical analyses of land							Moisture equivalent	Approximate	
			Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay		Wilting coefficient	Total moisture holding capacity
	lb.	%	%	%	%	%	%	%	%	%	%	%
1	1,200	3·70	2·14	7·24	12·85	37·55	18·93	10·17	11·12	18·71	10·17	50·37
2	600	2·98	1·09	2·67	4·35	22·72	34·29	29·94	4·94	14·32	7·78	43·48

Depth of soil, 0 to 12 inches.

mature leaf. In the Sumas environment, especially in wet seasons during late September and in October, flue-cured tobacco cannot be expected to properly ripen on soils of such fine texture.

Although not shown in Table XXII observations of the crop at harvest, indicate a progressive decrease in quality as yield increases beyond 800 pounds per acre. A yield of 1,200 pounds invariably denotes a soil as being too fine in texture for quality production. A yield of 600 pounds per acre is much too low for profitable production. Usually, but not always, a 600-pound yield produces leaf of lower quality than an 800-pound yield.

Other factors, environmental and cultural, being equal, invariably there exists a progressive correlation between soil texture and yield. Thus, the finer the texture of the soil, the higher the yield which may be expected. The 600-pound yield recorded in Table XXII, however, is an exception, the soil, although being much finer in texture than soil producing an 800-pound yield, yet yielding only a 600-pound yield. In this instance, it appears that the high proportion of silt, 29·94 per cent, depressed the yield.

Yield of Flue-cured Tobacco in Relation to the Moisture Equivalent, Wilting Coefficient and Total Water Holding Capacity

The higher the moisture equivalent, the finer the soil texture, the greater the capacity of the soil to retain moisture. Invariably, the higher the moisture equivalent, to about 12 per cent, the higher the yield and quality. Beyond 12 per cent, while yield invariably increases, quality decreases, the leaf being too large and coarse and too late in maturing. Sometimes, however, a soil having a fairly high moisture equivalent results in depressed growth and lowered yield, an example of which is given in Table XXII where a yield of only 600 pounds is recorded.

Table XXIII shows that a definite progressive correlation exists between yield and soil moisture relations. Although not recorded in this table, this progressive correlation also includes quality.

Table XXIII.—Yield of Flue-cured Tobacco in Relation to the Moisture Equivalent, Wilting Coefficient and Total Water Holding Capacity

Soil No.	Estimated yield per acre	Moisture equivalent	Approximate	
			Wilting coefficient	Total water holding capacity
	lb.	%	%	%
1	1,200	18·71	10·17	50·37
2	800	11·18	6·07	38·16
3	700	7·89	4·28	33·39
4	300	6·47	3·57	30·69
5	100	6·13	3·33	30·62

Soil Nos. 1, 3 and 5 are the average of two determinations. Soil Nos. 2 and 4 are the average of eight determinations. Depth of soil, 0 to 12 inches.

Yield of Flue-cured Tobacco in Relation to Soil Moisture Relations by Years, 1931-1932

Table XXIV, 1931 section, shows a balance between the total moisture holding capacity and the actual moisture content of the soil. This balanced moisture relation indicates that the almost continuous heavy rain which prevailed during early September, practically saturated the soil. Moreover, almost all this moisture was available for plant growth.

This saturated soil condition was most unfavourable for the production of flue-cured tobacco. Instead of yellowing and ripening, the leaf took on a greenish cast, a condition which seriously depressed maturity. This saturated soil condition caused the leaf to remain green for two weeks, thus increasing leaf wastage and cost of production and decreasing quality.

During dry seasons, the moisture content and moisture available materially diminishes below the total moisture holding capacity as shown in the 1932 section of Table XXIV.

This ease of soil saturation works for and against the production of tobacco at Sumas.

TABLE XXIV.—YIELD OF FLUE-CURED TOBACCO IN RELATION TO SOIL MOISTURE RELATIONS BY YEARS, 1931–1932

Estimated yield per acre	Moisture equivalent	Approximate			
		Wilting coefficient	Total moisture holding capacity	Moisture content	Moisture available
	%	%	%	%	%
1931—					
800 lbs.	10·24	5·56	37·07	37·07	31·51
300 "	6·49	3·52	31·19	31·18	27·66
1932—					
800 lbs.	11·12	6·04	38·46	22·73	16·69
300 "	6·23	3·38	30·78	12·21	8·83

Depth of soil, 0 to 12 inches.
Precipitation during September in 1931 and 1932 was 10·03 and 2·35 inches, respectively.

In the spring it facilitates the rapid drainage of surplus water, thus assisting in preparing the land for transplanting.

During dry seasons in July and early August, especially on the lighter soil areas, the tendency for such soils is to rapidly dry out, thus depressing growth.

TABLE XXV.—THE MOISTURE EQUIVALENT, WILTING COEFFICIENT AND TOTAL MOISTURE HOLDING CAPACITY—BY PROFILE
(Normal Crop Producing Area)

Soil No.	Moisture equivalent	Approximate	
		Wilting coefficient	Total moisture holding capacity
	%	%	%
1	9·69	5·29	35·31
2	7·53	3·84	31·51
3	9·89	5·38	36·11
4	3·90	2·12	26·29
5	3·14	1·70	24·93
Average of profile surface to water table	6·83	3·67	30·83

Soil number designation

No. 1—represents the surface soil layer, 0 to 8 inches, replicated 12 times.

No. 2—the average of the 5 soil horizons from the surface to water table, the sum depth varying from 36 to 63 inches, and averaging about 50 inches, replicated 27 times.

No. 3—the clayey sand layers mostly varying 2 to 5 inches in thickness and usually located in the second and fourth soil horizons, replicated 3 times.

No. 4—the red and brown sands situated between the surface and water table soil horizons, replicated twice.

No. 5—the dark grey sand horizon at water table, replicated twice.

During last August and in September and October, particularly if the season is wet, and the crop is late, temporary saturation may occur, depressing maturity. However, with drier, brighter weather, soil moisture rapidly decreases to the approximate requirement for ripening the crop.

In 1932, normal crop producing areas containing approximately 16 per cent available moisture during the ripening period of September, approached the nearest to the moisture requirement of this crop in the Sumas environment. This amount of available moisture combined with favourable weather conditions, promoted maturity and improved the quality.

The finer the soil the greater the moisture equivalent and soil moisture relations. This is well illustrated in Table XXV. Soil number 3, the clayey sand layers, possess the greater moisture equivalent, wilting coefficient and total moisture holding capacity, whereas soils numbers 4 and 5, the red brown sands and dark grey sands, possess the smaller soil moisture relation values.

Thus at Sumas, areas possessing soil where the clayey sand layers are well developed are invariably the most suitable for the production of bright flue tobacco.

SUMMARY

Soils of the Burley Tobacco Producing Areas of the Southern Interior

1. The principal Burley tobacco producing area is at Kelowna.
2. In general, the soils of the Burley areas are characterized by a pH value of about 7, being practically neutral, neither acid nor alkaline. The organic matter averages less than 5 per cent. The proportions of gravel, sand, silt and clay average approximately 3, 62, 26 and 9 per cent respectively. The soils vary from sand, to loam, to clay, with a very fine sandy loam predominating. These very fine sandy loam soils may be considered suitable for the production of Burley, provided the crop receives judicious husbandry.
3. The character of the sub-soil and underlying soil strata, the height of the water table, and exposure, may influence the irrigation requirement of a tobacco crop to a greater extent than the character of the surface soil. In general irrigation is required.
4. Under irrigation, the tendency of the loam soils is to produce a heavy yield of large coarse leaf.
5. Gravelly soils should be avoided in the culture of Burley.
6. Sandy soil of coarse texture which may be considered as being suitable for the culture of flue-cured tobacco, is limited to a very small scattered acreage. The culture of this type of tobacco has not been successful in these areas.
7. Approximate satisfactory soil moisture relations are most difficult to obtain on the variable soils typical of these areas. The irrigation of tobacco may be expected to present major cultural problems. These problems can be determined only by actual cultural experience of the particular environment under which the crop may be grown. Invariably, the environment is different on each farm.
8. The results of experiments indicate that where irrigation is practised, water should be sparingly applied.
9. A good crop of Burley was grown on a soil containing about 8 per cent moisture during the growing season. Of this amount, about 3 per cent was available for growth.
10. Bench soils containing a moisture equivalent of about 12 per cent are suitable for burley production.
11. Bench soils containing a moisture equivalent of about 9 per cent are unsuitable for flue-cured tobacco production the moisture equivalent being too high, indicating soils too fine in texture for this type of tobacco, the leaf being too large and coarse to secure desirable quality.

12. Soils having a lower wilting coefficient than 5 per cent are considered unsuitable for profitable tobacco production of any type.
13. At Summerland, on bench land, the moisture content of field samples of soil was found to be below the moisture equivalent.
14. At Summerland, the total moisture holding capacity of bench land consisting of gravelly loam and sandy loam soil is seldom realized by natural precipitation or by irrigation, if judiciously applied.
15. In the southern interior areas, the culture of tobacco of any type under soil conditions of total moisture holding capacity may be expected to very materially depress normal growth and develop major disturbances within the plant, especially that of frenching, a physiological disease.

Soils of the Flue-cured Tobacco Producing Area at Sumas, Lower Mainland

1. Geologically, the Sumas Lake deposit is probably of recent age.
2. The soil is derived by alluvium and glacial drift deposits.
3. The lake area was drained in 1924.
4. The water level of the area is protected by a dyking and pumping service.
5. The tobacco producing area is situated about sixty miles southeast of Vancouver.
6. Practically the entire area is level open land.
7. The climate is moderate. During the growing season there is little danger of frost or hail. Wind and rain are the major climatical conditions to be considered in the culture of tobacco in this area.
8. In normal crop producing areas, the soil from the surface to the water table contains higher proportions of organic matter, silt and clay than poor crop producing areas. While these higher proportions are not large, they are sufficient to materially influence crop production. The results indicate that the proportion of clay and silt to sand, is, to a large extent, the major soil factor influencing crop production.
9. The present degree of soil acidity appears to be derived from the original constitution of the soil and not from the effects of humus or commercial fertilizers. In general the acidity is rated medium, being approximately pH 6.
10. As yield increases beyond 800 pounds per acre, a progressive decrease in quality is noted. A yield of about 1,200 pounds per acre invariably indicates a soil much too fine in texture for quality production. Usually, but not always, as yield decreases below 800 pounds per acre, quality decreases. Other factors being equal, the lower the yield, the coarser the soil texture.
11. The finer the soil texture, the higher the moisture equivalent, the greater the capacity of the soil to retain moisture and sustain plant growth during hot dry weather. Thus, areas possessing soil where the clayey sand layers are well developed are the most suitable for the production of flue-cured tobacco, provided the moisture equivalent of the soil does not exceed 12 per cent.
12. A definite progressive correlation exists between yield and the moisture equivalent, also between yield and soil moisture relations. This progressive correlation also includes quality.
13. Invariably, the higher the moisture equivalent, up to about 12 per cent, the higher the yield and quality. Beyond 12 per cent, while yield increases, quality decreases, the soil being too fine in texture, resulting in the production of large, coarse, late maturing leaf.

14. During prolonged heavy rain, the tobacco producing soils at Sumas rapidly reach their total moisture holding capacity. Furthermore, on soil where the moisture equivalent exceeds 12 per cent, the total moisture holding capacity and moisture available are invariably too high to promote early maturity which is so very necessary for the successful production of this crop.

Acknowledgments

Mr. J. E. Britton, Assistant Superintendent, photographed Plate II, and Mr. C. P. Nelson, a local photographer, photographed Plate I and Figures I and II.

The Dominion Department of the Interior, Ottawa, made the map showing the tobacco districts in Southern British Columbia.

Mr. R. C. Palmer, Superintendent, read the manuscript and made various helpful suggestions.

Mr. C. C. Kelly, Provincial Soil Specialist, Kelowna, B.C., read the manuscript and made various valuable suggestions.

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Soil Terminology

Organic matter: The more or less decomposed material of the soil derived from organic sources, usually from plant remains.

Soil profile: A vertical section of the soil from the surface into the underlying unweathered material.

Soil horizon: A layer or portion of the soil profile, more or less well defined and occupying a position approximately parallel to the soil surface.

Heavy: Applied to soils of fine texture.

Light: Applied to soils of coarse to medium texture with very low silt and clay content.

Ottawa: Printed by J. O. Patenaude, Printer to the King's Most Excellent Majesty, 1935.